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PHOTOGRAMMETRIC MEASUREMENTS IN GEOTECHNIC

FOTOGRAMETRICKÉ MERANIA V GEOTECHNIKE

Abstract

Photogrammetric measurements have unsubstitutable place in geotechnic for data acquisition in hardly accessible localities, mainly in evaluation of the stability of rock masses and evaluation of the intensity of weathering in rock cliffs as well (rock quarries, cuts, bench cuts etc.). The paper is recording the principles of the photogrammetric methods and their applications in the several localities in Slovakia.

Key words: close range photogrammetry, stability monitoring of rock environment

Abstrakt

Fotogrametrické merania majú v geotechnike nezastupiteľné miesto pri zbere údajov v ťažko dostupných územiach, hlavne pri hodnotení stability skalných masívov ako aj pri hodnotení intenzity zvetrávania v skalných stenách (lomy, zárezy, odrezy a pod.). V príspevku sú uvedené princípy niektorých fotogrametrických metód a ich aplikácií na Slovensku.

1 INTRODUCTION

Based on the analysis of the engineering geological causes of the failure of building structures mainly historical objects situated on the exposed rock masses follow that the most frequent engineering geological causes of the failure are the changes in geological environment caused by the geodynamical processes.

They are mainly slope gravitational phenomena, although the weathering process, erosion and karstification influence is also nonnegligible, eventually the influence of more phenomenons at the same time (Baliak, 2009). Erosion and transformation of the rock are the other geodynamical processes which participate in the rock mass and cuts failures. Besides the geodynamic phenomena, the considerable role is played by the influence of underground water, geodynamic influence, superimposed loading and unloading (Vlčko et al., 2002).

The main requirement for the overall valuation of the stability of the castle rocks is the acquisition of the exact quantitative data about main parts of the engineering geological conditions (rock, underground water and relief), about their development and various interactions what means the natural geological processes and their interaction with the engineering works, (i.e. about the impact of the geological factors on the construction and backwards the anthropogenic geological processes consequently activated). For a long time photogrammetry plays an important role in the process of obtaining data about rock mass as one of the mapping methods.

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This paper documents the main photogrammetric methods and instruments used in the geotechnical monitoring and illustrates them on the examples of the before and after remediation measurements of certain objects in Slovakia.

2 SUBJECT OF PHOTOGRAMMETRIC MEASUREMENTS IN GEOTECHNIC

The failures of rock masses can be worked out using data obtained by photogrammetric methods. Especially the methods of close range photogrammetry are suitable from the wide range of exploitation. Photogrammetric methods are used in:

- exact presentation of the morphology of rock mass,
- engineering geological interpretation of main characteristics of rock mass by profiles,
- determination of the structural, lithologic and tectonic border lines,
- data acquisition about location and density of discontinuity,
- data acquisition about blockiness of rock mass,
- identification of quasi-homogenous entities according to the stability of rock masses,
- after-remediation control measurements of geotechnical elements and mass.

Obtained data are used for explanation of the object failure causes in interaction with rock mass which are base for the suggestion of remediation, reconstruction or conservational arrangements (Baliak, 2009).

3 CLOSE-RANGE PHOTOGRAMMETRY IN GEOTECHNIC

Close range photogrammetry is characterized by object capture distances under 300m. Most of the geological or geotechnic application allows taking pictures even from the distance about 30m what means one order higher accuracy and allows photographic record with very high resolution (high density of pixels) on the surveyed object. Photogrammetric methods can be characterized following (Fraštia, 2009):

- indirect measuring method – measurements on the images which were created by central projection in optic way (visible light, close infrared light, RTG radiation),
- contactless measurement (in contrast to geological methods),
- range of the object sizes from millimeters up to 100m,
- precision from 0.001mm to 0.1m,
- remarkable reduction of the terrain works,
- high temporal resolution (1s), capturing the state of the object in short time period (from 0.001s),
- image has high informative value about qualitative and quantitative attributes of the object (documentation and archival purposes),
- it is possible to get back to the object on the image and measure data again,
- precision decreases according to the longer distance from the object,
- precision is one order better for signalized points,
- today only the digital photogrammetry is in use,
- possibility of the usage of the amateur cameras and low cost software,
- digital photogrammetry provides the automated processes of image processing (significant increase of effectiveness and accuracy).

3.1 Cameras used in close range geotechnic applications

Geometric and radiometric image quality is a significant factor affecting final accuracy of the photogrammetric measurement. The important parameters of the image are:

- size,
- scale,
- spatial (geometric) resolution,
- radiometric resolution,
- distortion.

For the photogrammetric purposes large image formats are the most suitable and therefore the photogrammetric cameras are produced according to this requirement. Arrival of digital photogrammetry made the process of determination of spatial coordinates more effective and accurate and enabled using even the nonprofessional cameras. Brief review, characteristic and cameras categories used up to now for geotechnic purposes by Department of Surveying are in table 1:

Tab.1: Cameras used for geotechnical applications on Department of Surveying

Camera	Type of camera	Image format [mm]	Focal length [mm]	Relative precision	Price in year
 **Zeiss UMK 1318**	Analogue metric	180 x 130 Large format	200 100 60	from 1 : 20.000 to 1 : 200.000	250.000 Kčs 1970
 **Rollei 6006**	Analogue semi metric SRL	60 x 60 Middle format	120 80	from 1 : 10.000 to 1 : 100.000	125.000 Kčs 1980
 **Nikon D200**	digital SRL amateur	24 x 16 Small format	20	from 1 : 3.000 to 1 : 10.000	60.000 Sk 2006
 **Phase1 Aptus7 II**	Digital back + SRL	48 x 36 Middle format	80 45	from 1 : 10.000 to 1 : 100.000	25.000 € 2009

Comment: Relative precision express ratio of reached precision to object size.

4 MAIN PHOTOGRAMMETRIC METHODS

Evolution of the digital photogrammetry went from analogue evaluation through analytical to digital image processing (digitalized primary or secondary using scanner). Nowadays there are 4 main approaches of processing the digital images in the Department of Surveying which explicitly relate to the methods of image capturing used in terrain:

- time baseline,
- convergent image processing,
- normal position images processing using stereo evaluation,
- normal position images processing using image correlation.

4.1 Time baseline

Time baseline is using the object images captured from the identical station and with the same camera orientation but in different time periods. Evaluation is basically stereoscopical whereby there is a massive parallax on the places where the displacement change occurred. This is register by an evaluator as a depth change in the stereomodel. Parts of the model without changes stay in the same plane. This method is one of the most accurate methods but there is a disadvantage in a possibility of change detection only in the plane parallel with the image one and it is necessary to know the distance between the observed point (part of the rock mass) and the image capturing station. In practice this method is used mostly in the measuring the displacements of rock mass in vertical plane perpendicular to the mass.

4.2 Stereophotogrammetry

Stereophotogrammetry is very effective method used for the direct measurement of spatial coordinates on the stereoscopic model. Measurements on the rock masses are usually realized in form of point measurements or measurement of horizontal and vertical profiles. This way it is possible to determine for example geological discontinuities or display exact and detailed profile through the mass on the selected places of interest. As an example we can use control phase measurements of rock cuts using profiles for determination of change in selected profiles with sub centimeter precision (fig. 1 and 2).

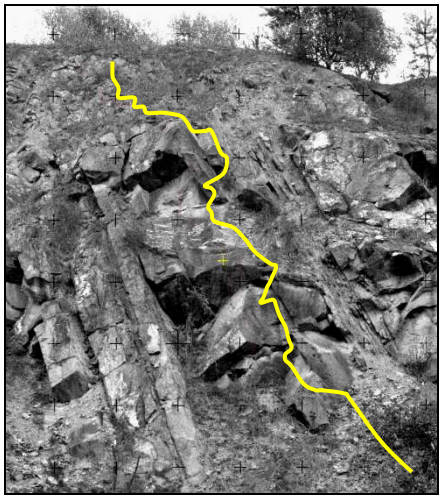

Fig.1: Perspective draw of profile to image

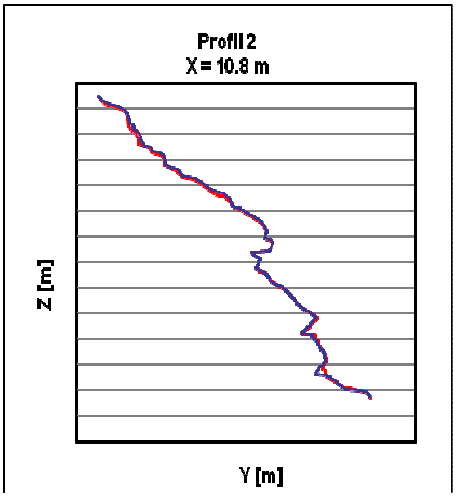

Fig. 2: Interpretation of measured profile

Photogrammetric image, respectively stereomodel is a big help for geological interpretation of rock slopes as well as you can see on the figures 3 and 4.

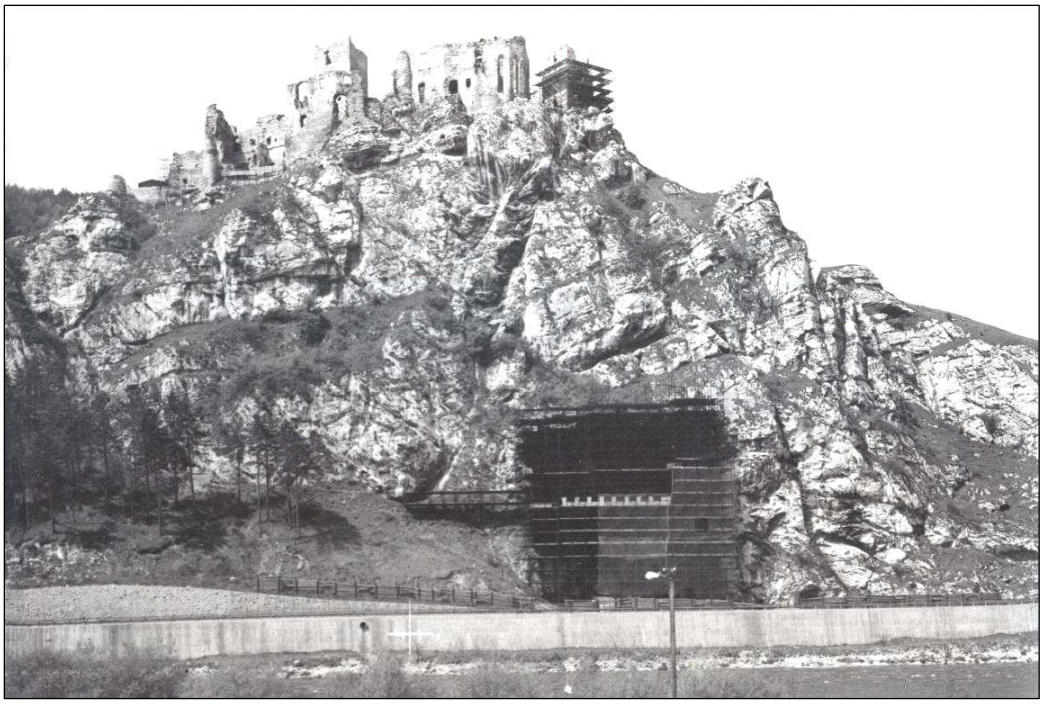

Fig.3: Strečno – castle rock before remediation, 1981 (photo P. Bartoš)

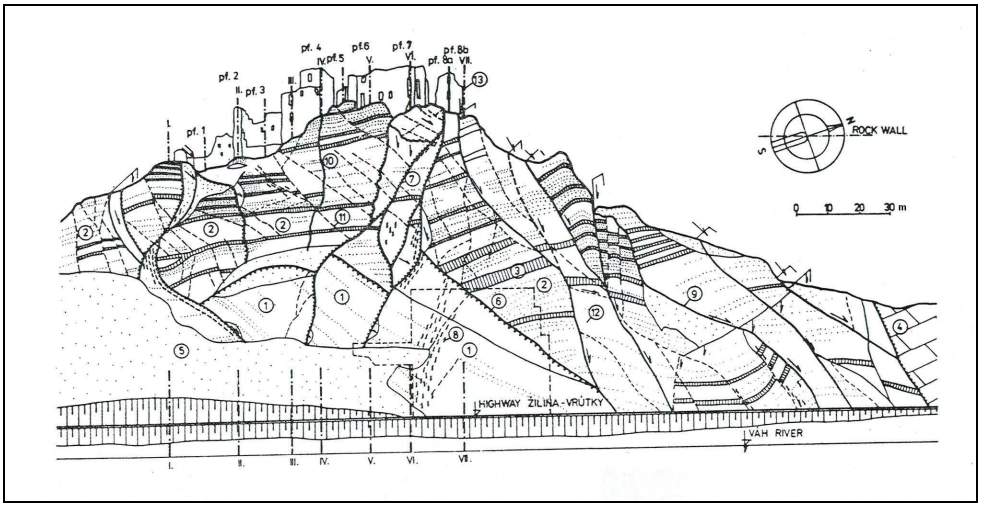

Fig.4: Geological interpretation of the photo done from stereoscopic processing in comparator STEKO 1318 and from direct geological survey

Irreplaceable exploitation of photogrammetry is in displaying the geologic situation and suggestion of remediation into the directly measured profiles determined in advance by geotechnic (fig. 5 and 6, Malgot, 1981):

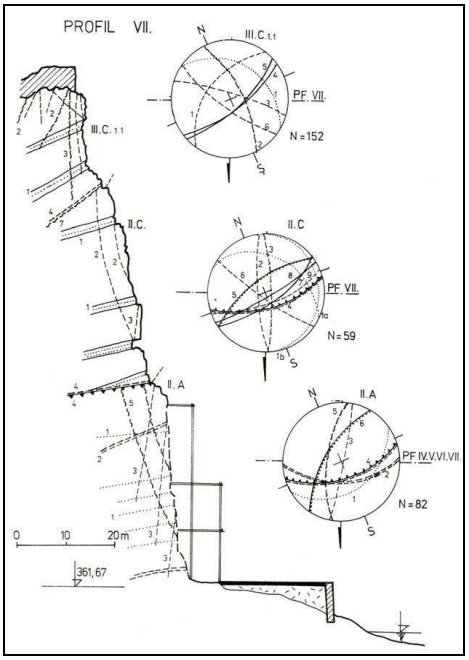

Fig.5: Profile through castle rock (Strečno)

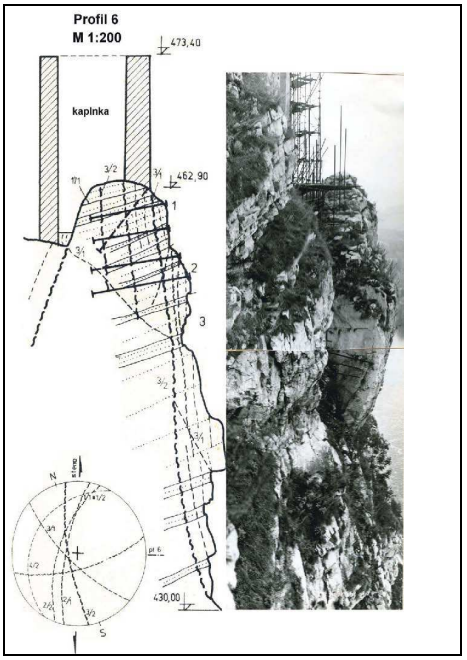

Fig.6: Detailed profile with design of remediation of castle basis

4.3 Convergent photogrammetry

Convergent photogrammetry is the most precise photogrammetric method which with the suitable configuration of stations achieves the homogenous precision in all 3 axes XYZ of object space. Images are captured in the way that the optic axes are convergent and the object should cover the maximal space on the all images and all the angles of intersection on the determined points should be in the range 60º-120º (fig. 7). At the same time it is the most hardworking method unless it is possible to use the automated tools of points measuring and identification.

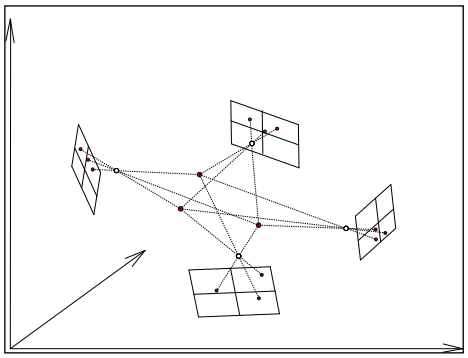

Fig.7: Convergent images

Fig.8: Rhyolite cliff in Vyhne village

Convergent photogrammetry was used for after-remediation monitoring of geotechnical arrangements for the rock mass stability securing. Rhyolite cliff in Vyhne (fig. 8) is close to the Brewery Steiger on the northeastern slope over the state road in the elevation 306-360m above sea level. The base of the cliff is 306-335 meters and the top of the cliff 331-360 m above sea level. Observed exposed part of the cliff with the cranked footprint is in average 75 m long and 26m high with the slope of the front face 80-90^0 (Holzer et. al, 2000). After accident when few tones block had fallen down and threaten the brewery, there were suggested and realized remediation arrangements. After-remediation monitoring consisted of the photogrammetric observations of approximately 300

anchors where the observed points were signalized by corners of the plates on the remediation anchors. Measurements were realized in 3 phases – primary one and 1st and 2nd control ones. Spatial accuracy on the observed points reached the values maximum 10mm within the entire rock block (Fraštia, et. al, 2000). Subsequent statistic analysis did not show instability of the individual blocks in regards to each other.

4.4 Photogrammetric scanner

Photogrammetric scanner is measuring technology based on the automatic generation of 3D points using principles of image correlation and epipolar geometry. It is not the hardware solution but the algorithm of image processing. In the point of accuracy and way of image capturing it is methodically case of stereophotogrammetry but the way of evaluation is on principle different. The result is so called point cloud in certain grid which can be minimum 1 pixel. However it can be few mm in short object distances. Photogrammetric scanner technology is suitable mainly for detailed modeling of rock relief. An advantage of this method is low costs of instrumental and software equipment, minimal terrain works and especially high level of automatization of image processing. Requirements for the high quality results are high quality inputs what means high quality images without defocusing and noise.

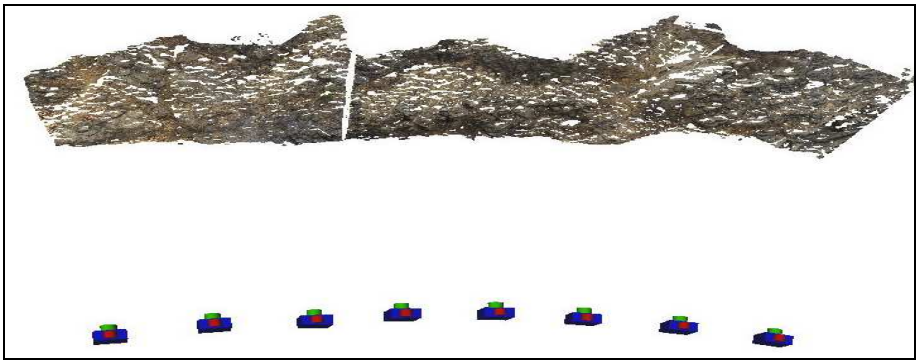

Fig.9: Generated point cloud with 5 cm grid (cliff size 50m x 15m, Banská Štiavnica)

Fig.10: Detail of point cloud with 10 mm grid, size of block 1.5m x 1m

Practical experiments confirmed that this method is not suitable for generating the high density point clouds on the objects with the significant depth segmentation where a lot of noise (incorrect points) occurs. Optimal application of this method would be mainly in the creating of the digital relief model of large rock masses with the precision higher than 0.5m as well as modeling of the microrelief of smaller areas (up to 2m x 2m) of rock masses with the precision higher than 1mm (Fraštia, 2009).

5 CONCLUSION

Main task of the engineering research for the static securing the construction works is explanation of the basic conditions, factors and causes of their failure formation. This task is solvable only within the close cooperation with the full range of specialists because failure causes can be activated by different reasons as well.

Apart from the complete research of the foundation soil using bore and borrow holes it is generally necessary to make also whole range of additional works for the unique specification of the failure formation causes. Suitable ones are mapping, geophysical, surveying and leveling observations and methods of close range photogrammetry. The regime of the displacements on the cracks, block settlement, dynamic of the slope displacements, eventually the regime observations of the underground water level are observed using different methods.

Practical output of engineering geological research should be ideological proposal of effective remediation. Remedial interference should be suggested in the way to eliminate the failure formation causes and to secure a sufficient stability.

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